Investigation of Data Transfer Capabilities for Heterogeneous Service Support in Critical Mobile Objects Communication Situations

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Abstract. Research of heterogeneous service providing in the fast-changing topology vehicular communication networks are important because expansion and integration of this intelligent transport systems platform would greatly improve traffic safety and reduce injuries on the road. At the same time, the trips would be more comfortable. In this work, it is investigated data-transfer capabilities for heterogeneous service support, road safety, assessed their integration potentials and prospects in vehicle communication networks with changing topology. It is showed that to provide quality heterogeneous services it is necessary new routing protocols and channel access methods for the large volume fast changing topology networks.

Keywords. Multimedia services, vehicular communication networks, routing ad-hoc networks, mobile nodes, changing topology

Introduction

Today, the vehicle is a very important component of human life, so installed intelligence based software and hardware equipment, can improve the level of travel safety and comfort. Currently, one of the most attentions attracting mobile communication technology is vehicular wireless communication networks. They offer the potential to develop and produce safer, more reliable, economic and comfortable vehicles. These networks are gaining more and more commercial relevance, since the adoption of DSRC (Dedicated Short-Range Communication) / IEEE 802.11p (Wireless access in vehicular environments (WAVE)) standards in both the EU and the U.S., given the possibility to reach an entirely new level of service in a vehicle, covering many areas, including road safety, traffic management, comfort applications. Vehicles do not have strict restrictions on power consumption, and therefore, can be easily equipped with powerful computing devices, wireless transmitters, sensors, complex

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systems - GPS, photo / video cameras, vibration, acoustic, chemical sensors and, etc. [1].

Practices of vehicular communication network's deployment, research and scientific projects are developing in two directions: direct vehicle-vehicle (V2V) communication and vehicle-to-infrastructure (V2I) communication [2]. Research in this area addresses many complex communication problems as there are many specific determinants of the quality of communication, including highly dynamic traffic and communication conditions, frequent disconnection of nodes as well as heterogeneity of data transmission links.

This paper explores the evaluation of the data-transfer efficiency in a mobile communication network when the sender and the receiver is moving in opposite directions at high speed. It is organized as follows: in Section 1, we analyze the vehicular communication networks and their architecture, in Section 2, we briefly present related works. Section 3 describes the experiment methodology and simulation model. In Section 4, we provide the simulation results for our model. Section 5 offers our conclusions and prospects for future research.

1. Vehicular Communication Networks and Their Architecture

Vehicular communication networks can be formed spontaneously between the moving nodes that are equipped with the homogeneous or heterogeneous wireless interfaces (802.11a/b/g/n/p, WiMax, 3G, LTE and so on.). These networks, also known as the VANET (Vehicular Ad-Hoc Network) is one of the MANET (mobile ad-hoc network) applications, allowing communication between the nearby vehicles and vehicles and stationary equipment (road side units). Vehicular communication application areas can be divided into three main categories: general information - multimedia services, road safety and traffic monitoring and management services [2].

An analysis of the scenarios where the communication is made between the sender and the recipient moving in the opposite directions was made; it is given in Table 1.

Table 1. Scenario analysis of the vehicular communication network

	Rural	Town	City	Highway
Average speed of the nodes	Average	Low	Very low	Very high
Node density	Low	Average	Very high	Average/low
Interference	Low	Average	Very high	Low

1.1. The Specific Characteristics of the Vehicular Communication Networks

Vehicular communication networks have special characteristics and properties that distinguish them from other types of mobile communication networks. According to [3] and [4], it was summarized the following unique features:

- High energy reserve;
- Huge mass and size of the vehicle;
- Moving by the patterns.

Vehicles have much greater energy reserves, compared with a conventional mobile device. Energy can be obtained from the rechargeable battery and gasoline, diesel or alternative-fuel motor. The vehicles are many times greater and larger compared to traditional wireless devices, and therefore, can support a much greater and heavier computing, radio and sensor components. Computers can be bigger, faster, and provide very high-capacity memory devices (terabytes of data), and powerful wireless interfaces, capable of high speed communication. The vehicles can move at very high speed (160 km/h or more), making it difficult to maintain a consistent, coherent V2V communication. However, the existing statistical data on vehicle movements, such as the movement together according to certain patterns or peak time can help to maintain a link between the mobile automotive groups. Vehicle at any time may be out of communication coverage (WiFi, cellular, satellite, etc.), so the network protocols must be designed so that it can easily connect to the Internet, in normal mode. Despite the many positive unique features, vehicular network's development is faced with specific challenges, as their primary:

- Large-scale networks;
- High level of mobility;
- Fragmentation of the network;
- Changing topology;
- Complex communication quality assurance.

Unlike the literature described ad-hoc networks, which are quite limited in size, vehicular communication networks, in principle, can extend across the road network and cover a huge amount of network equipment (vehicles). The environment in which networks are operating is extremely dynamic and, in some cases it may be highly different, for example, in highway speeds can reach up to 300 km/h, in the low-density roads car density may be as only about 1-2 cars kilometer. On the other hand, the speed of cars in urban areas is 50-60 km/h and the car density is quite high, particularly during the peak periods. Often vehicular communication networks may be fragmented.

The dynamic nature of traffic can lead to large gaps between cars in sparsely populated areas; it can also be created a few isolated clusters of network nodes. Vehicular communication networks' scenarios are highly different from the classic ad-hoc networks, since the cars are moving and constantly changing positions, scenarios are highly dynamic. Furthermore, the network topology changes extremely frequently, since the very frequent connections and disconnects between network nodes. In fact, the degree to which the network is combined depends on two factors: the distance between the wireless nodes and number of connected vehicles [5].

2. Related Work

There is a growing literature on data-transfer capabilities for heterogeneous service support within vehicular networks, some of which have also considered the application of our analyzing problem. We briefly discuss the key the most recent relevant references next, and highlight their difference from our approach.

Analysis of the performance of DSRC-based VANETs in delivering CVSS (Cooperative vehicle safety systems) messages was made in [6]. Here a network performance measure is defined, which can be used as an indicator for the success of

CVSS tracking application. A study into how controllable parameters such as rate and range of transmission affect this performance measure has revealed interesting properties of IDR. It is shown that robust control of rate or range of transmission based on the relationship between IDR and channel occupancy is possible. Based on these concepts, a robust range control method is analyzed and evaluated.

Another performance evaluation of information propagation in a vehicular ad-hoc network was made in [7]. The authors' studies packet loss rate, expected transmission distance and effective coverage range of road-side station. They state that communication performances are similar under three distributions in most cases where negative-exponential distribution shows the worst performance. It can be assumed that under negative-exponential distribution, the randomness of space headway is strong, this will break down the connectivity of the communication chain.

In [8] presents results for 35 field trial data sets collected in Australia, Italy, Germany, Austria, and the United States, covering over 1100 km on the road in a wide variety of physical environments. The performance results reveal that DSRC/ WAVE can provide highly reliable communications, and sufficient driver warning times in support of the targeted road safety applications. However, analysis of channel sounding data collected shows that NLOS safety-critical conditions require careful attention to physical layer receiver processing in order to provide a safety benefit.

The performance modeling of message dissemination in vehicular ad-hoc networks with two priority classes of traffic was presented in [9]. The results showed that the probability of a receiving node being exposed to interference increases as a function of the transmission range, and that this increase is faster at higher-density node traffic.

Performance of the 802.11p Physical Layer was estimating in the [10]. Authors have found that the primary problem is that the channel estimation mechanisms built into the 802.11p standard only allows for channel estimation at the beginning of each packet. Because the packet length is not restricted by the standard, the initial channel estimate can expire before the packet has completed transmission. They state that, the channel estimate must be updated throughout the length of the packet. Furthermore, authors make the conclusion that the maximization of throughput is a tradeoff between high overhead at short packet lengths and poor performance at longer packet lengths.

Nevertheless, the growing number in of researches in terms of data-transfer capabilities in vehicular communication networks, none of them investigates a special scenario where the nodes are moving in the opposite direction in a highway. From this point of view, our work is different and novel.

3. Methodology and Experimental Model

As it was mentioned in the previous section, the services in the vehicular communication networks can be classified into the road safety, information and multimedia services' categories. To support high-quality services it must be taken into account the data rate, packet delivery efficiency and collision rate. The analysis shows systematic data quality requirements for different services for vehicular communication networks (Table 2). To determine the influence of the number of vehicles in connection capacity it was made a number of experiments which goal is to evaluate data-transfer efficiency when providing mobile multimedia services in the communicative network between in the opposite directions moving sender and receiver nodes at high speed.

Table 2. Data transmission quality requirements for different services support in vehicular communication networks, by the [11, 12]

Service	Packet size (in bytes) / required throughput (KB/s)	Packet loss influence	Periodicity of transmitted data	Tolerated latency (ms)
Road safety services				
Lane changing	~100 / 1	Average	Event	~100
Traffic light control	~100 / 1	Average	Periodic	~100
Warnings about dangers	~100 / 1	High	Event	~100
Warnings on road conditions	~100 / 1	Average	Periodic	~100
Multimedia services				
IPTV	~1300 / 500	Average	Periodic	<200
VOIP	~100 / 64	Average	Periodic	<150
Video/audio files exchange	As high as possible	High	Periodic	-
Games	As high as possible	High	Periodic	-

The experiments were carried out in the simulation environment NCTUns 6.0 [13], which was installed on Fedora 12 Linux operating system. The environment was chosen as it uses the existent Linux TCP/UDP/IP protocols stack, it provides high-accuracy results; it can be used with any actual Unix application on a simulated node without additional modifications; it supports 802.11a/b/p, 802.16e communication networks and vehicle mobility modeling, user-friendly user interface, and it is capable of repeated the simulation results. In the experimental scenario (Figure 1), a node (4) sends data to the node (11). Communication is provided via 801.11b standard interface and is used multi-hop data transmission method.

It was analyzed and structured requirements for the NCTUns simulation model (Table 3). The experiment was carried out when the number of nodes in the network is from 10 to 100 - simulating different traffic congestion to determine the impact of the vehicle's number for the data-transfer efficiency. Senders and receiver's nodes are moving at high speed (130 km/h) in the opposite directions. The remaining vehicles are moving at different speeds from 90 km/h to 150 km/h, and their speed and directions of movement are spread evenly. These parameters are chosen to simulate the realistic movement of cars on highway conditions.

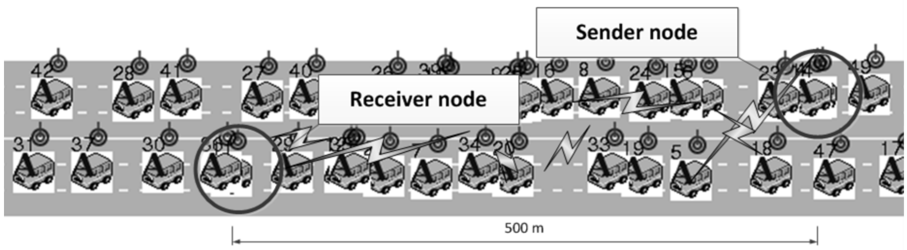

Figure 1. The experimental scenario

Table 3. Simulation parameters for the experiment

Parameter	Value
Simulation time	60 s
Physical layer protocol	802.11b
Number of nodes	from 10 to 100
Nodes mobility model	Random, highway
Channel frequency	2,4 GHz
Routing protocol	AODV

4. Experimental Results

During the experiments, it was evaluated data transmission efficiency – outgoing throughput, download throughput, packet drops and collisions with a different number of vehicles on the network. The data was transmitted using the UDP protocol, and a packet size of 1000 bytes. Simulation was carried out for 60 seconds. The assumption was made that the communication time between the sender and the recipient is directly proportional to the number of cars on the network. Furthermore, with increasing number of nodes it is expected to increase the collision rate and rejected packets.

Analysis of the data collected during the experiments shows the download speed versus time, with a different node's number on the network (Figure 2). The graph shows that the longest communication time is achieved by operating the largest network of vehicles - 100. With the maximum number of vehicles, the network coverage increases, so the data can be transferred for a longer period of time. With 100 vehicles and about 330 KB/s data transfer rate, we have managed to maintain communication for 30 seconds. The speed from 31 s decreased to 50 Kb/s, but from 37 s to 41 s the rate rises to 230 Kb/s, and from 46 s to 48 s - to 130 KB/s. When the vehicles passed each other the connection was lost. The minimum data rate was achieved by the network operating 50 vehicles. Moreover, in this case, the shortest communication time is achieved. With a small number of vehicles (10-30), it is maintained a relatively high data transfer rate, due to the low collision rate.

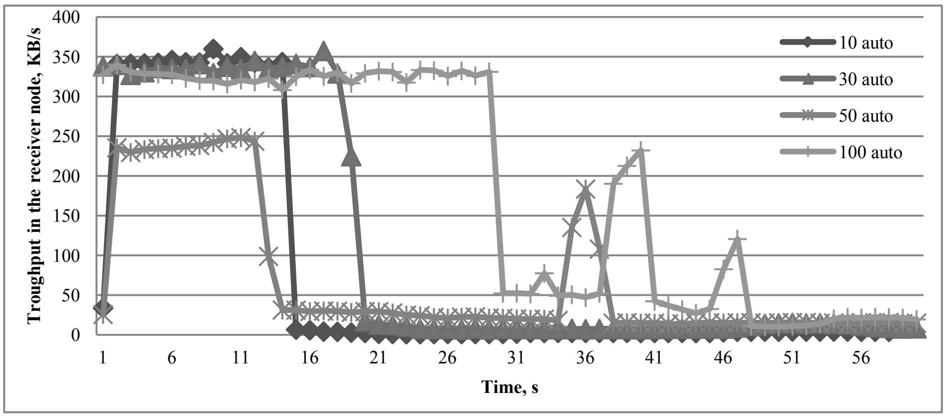

Figure 2. Data download rate dependence from time with a different number of vehicles in the network

After the experiment, the other important parameter - the average data uplink and downlink throughput was measured (Figure 3). In this case, the highest mean transfer rate achieved by the network operating 20 vehicles, while the meanest - 30. The maximum average data rate of downlink – 100 vehicles, while the meanest – 50.

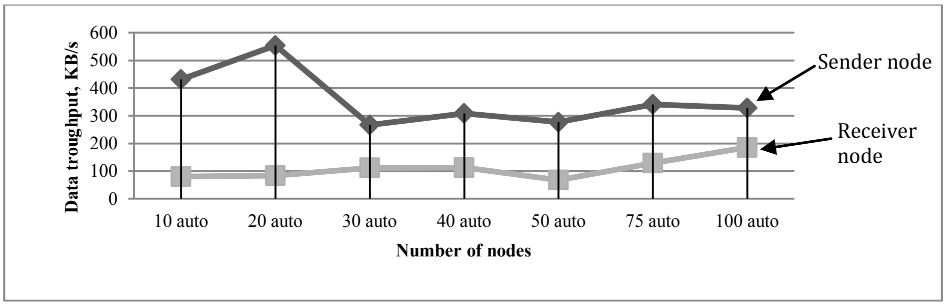

Figure 3. The average data downlink and uplink throughput with a different number of vehicles

It was found out collision's dependence on sender and receiver nodes with a different number of vehicles (Figure 4). Collision rate is directly proportional to the number of vehicles. Up to 40 vehicles, collisions rate at the receiver and sender nodes is similar, but from 50 vehicles, collision is greater in sender node because of unsuitable channel access mechanisms.

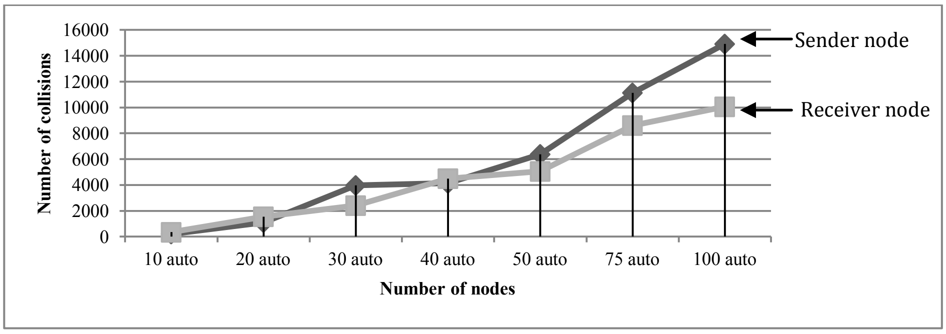

Figure 4. Collisions rate dependence on receiver and sender nodes with a different number of vehicles

5. Conclusions

It was performed the experiments in which was investigated communication and data-transfer efficiency between at high speed moving sender and receiver nodes in the opposite directions, in the mobile multimedia services communicative network. The goal was reached, and it was estimated the transmission efficiency and quality of communication. It was found that the longest communication can be maintained at the maximum number of vehicles, but that communication quality is inversely proportional with the number of vehicles, as the increasing number of vehicles - increasing data and network flooding occurs in many collisions.

To provide quality heterogeneous services it is necessary new routing protocols and channel access methods for the large volume fast changing topology networks. This investigation is important because it examining problems associated with communication between the sender and the receiver moving in opposite directions in highway, where the network topology varies very rapidly and, which may contain from one to several hundred of the network nodes. Future plans to extend the study to include other proactive, reactive and hybrid (ADV, DSDV, AORP, etc.) routing protocols.

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